CHARACTERIZATION OF MARTIAN GEOLOGICAL UNITS BY MULTIVARIATE ("CLUSTER") ANALYSIS OF EARTH-BASED RADAR DATA. S.H.Zisk NEROC Haystack Observatory, Westford MA 01886; and P.J.Mouginis-Mark, Dept. Geological Sciences, Brown University, Providence RI 02912.

Introduction: Goldstone radar measurements of Mars during the 1971 and 1973 oppositions (1) provided a wealth of data that have enabled the topography (2) and surface characteristics (3,4) of the planet to be investigated. These measurements cover the latitude range 14-21°S, or about 6% of the martian surface. The data set contains about 32,000 point measurements of the radar signal and provides information on the altimetry, surface roughness (C-factor; ref.5), and dielectric constant (via inherent reflectivity) for a lateral scale of 0.1 - 10 meters (6) with an areal resolution of 1.3° (80 km) in latitude and 0.16° (10 km) in longitude (1). These three measured parameters represent mutually independent characteristics of the martian surface (5); any intra- or inter-regional correlations between these values would consequently suggest similar surface properties. We have been analyzing these data in conjunction with the Viking Orbiter images, in order to investigate the ability of the radar measurements to resolve martian geological and geophysical problems. In the present work, our intention is to determine if the radar data can be used for the investigation of the entire planet (rather than the local analyses of refs. 2-4), and if so to better understand the information so derived.

Analysis: In most of the areas we have studied so far (4,7,8), the radar measurements are not widely distributed in reflectivity and smoothness, but rather tend to be characteristic of the local surface. Our analysis has therefore been based on the following four postulates:

1) The martian surface is not random, but rather consists of an array of overlapping (or adjacent) geologiacl units.

2) The radar data is characteristic of individual surface materials, although not necessarily uniquely so.

3) The random variation of the radar measurements within a given unit is smaller than the difference between units.

4) The resolution of the radar is fine enough that most of the data points represent individual surface materials, rather than an amalgamation of two or more materials.

In the cases where these postulates are valid, a multi-dimensional histogram of the number-frequency of the radar measurements should reveal a clustering of the data corresponding to characteristics of the surface materials. Accordingly, Fig.1 presents a series of examples of such histograms, using the two-dimensional case of radar reflectivity versus smoothness. In Fig.1, the entire 1971/1973 Goldstone data set has been subdivided into eight longitudinal bands that approximately correspond to major geological provinces identified by Scott and Carr (9). This subdivision was experimentally found to be necessary due to the extent of the clusters within each histogram. Were all the data displayed at once the multiplicity of the clusters originating from widely separated regions of the surface would mask the existence of all of them.

The longitude boundaries in Fig.1 were selected so that the histograms represent the following surface materials:

1) 0-50°W: Cratered plateau material within the southern highlands. This segment also includes the southern rim of Eos Chasma.

Clustering Mars Radar Data

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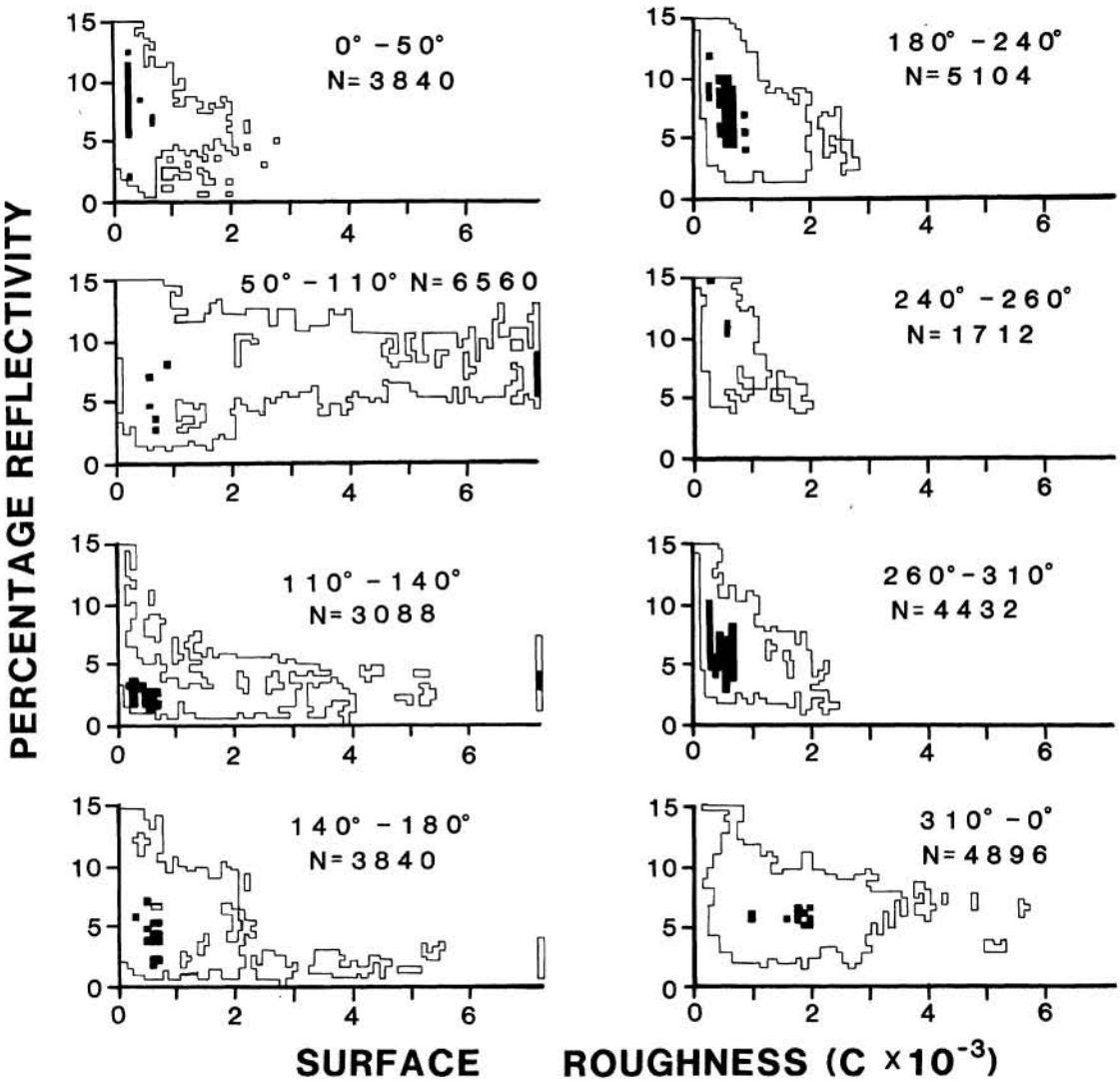

Fig.1: Two-dimensional cluster diagrams for the eight regions of the martian surface described in the text. Contours are at 15% (open outlines) and 80% (filled outlines) of the highest number density of points in each region. Thus the shapes of the histograms are accurately represented, as opposed to the numbers of data points. Bin size is 200 in C-factor and 0.5% in reflectivity. "N" gives size of each sample for the given longitude range. All data are from ref.1.

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2) 50-110°W: Ridged plains south of Valles Marineris. This area includes the plains units within Syria and Sinai Planitia, together with the previously recognized radar anomaly associated with Solis Lacus (8).

3) 110-140°W: Lava flows south of Arsia Mons (7).

4) 140-180°W: A combination of cratered plateau and hilly and cratered materials in the Memnonia Fossae region (4).

5) 180-240°W: Predominately hilly and cratered terrain with some areas of cratered plateau materials. Morphologically, this area resembles Memnonia.

6) 240-260°W: Hesperia Planum, including the old dissected volcanoe Tyrrhena Patera. The surrounding plains units illustrate wrinkle ridges that are

similar to those seen to the south of Valles Marineris.

7) 260-310°W: Hilly and cratered terrain, probably possessing the highest number of large degraded craters for any area investigated here.

8) 310-360°W: Cratered plateau material. This area contains a smaller population of craters than the hilly and cratered terrain and has flat and smooth intercrater areas.

Discussion: The shape of each radar cluster diagram permits several inferences to be made concerning the characteristics of the surface and the quality of the radar data. In some cases it is clear from the histogram that the clustering is artificial, caused by the measuring or data-processing systems. For example, the hyperbolic form in the 110-140° segment of Fig.1 is believed to be associated with the very weak radar echo from the Arsia Mons lavas (3,7). In using the template-fitting technique developed by Hagfors (5), the weak-signal uncertainty in the calculated values for reflectivity and smoothness from such a surface has a tendency for an artificially low value for one of the paramters to be paired with an artificially high value for the other. Assuming that the processing error for the data were a constant factor multiplied or divided by the measured value, the calculated reflectivity and smoothness for such a surface would generate a hyperbolic curve similar to the one illustrated. Conversely, radar data with both high reflectivity and smoothness produces data points with a high degree of certainty (10). The wide distribution of the data for Solis Lacus (8,10) which appears in the cluster diagram for 50-110° (Fig.1) is, for this reason, an accurate representation of the martian surface with no apparent artifacts of the data processing. For the remaining six cluster diagrams in Fig.1, however, there appears to be more subtle characteristics of the surfaces that can be recognized from the radar data. Between 310-0°W for example, smooth reflective surfaces occur within the cratered plateau material that are absent from the hilly and cratered terrains. Cluster diagrams for the areas between 140-180°W, 180-240°W and 260-310°W are all similar (C-factor $<$1000, reflectivity 3-10%) and each corresponds to hilly and cratered materials. In contrast, the ridged plains within Hesperia Planum (240-260°W) typically have smoother surfaces (C-factor $<$2000) and always have a reflectivity greater than 5%. The cratered plateau material between 0-50°W is seen to possess a large number of very rough, highly reflective surfaces in comparison with the area between 310-0°W, and this is probably a consequence of the low echo-strength returns for the data derived from Eos Chasma.

References: 1) Downs G.S. et al. (1975) Icarus 26, 273-312. 2) Roth L.E. et al. (1980) Icarus 42, 287-316. 3) Schaber G.G. (1980) Icarus 42, 159-184. 4) Mouginis-Mark P.J. et al. (1980) PLPSC 11th, in press. 5) Hagfors T. (1964) J.Geophys.Res. 69, 3779-3784. 6) Evans J. & Hagfors T. (1968) Radar Astronomy, McGraw-Hill, NY. 7) Mouginis-Mark P.J. & Zisk S.H. (1980) LPS XI, 768-770. 8) Zisk S.H. & Mouginis-Mark P.J. (1980) Nature 288, 735-738. 9) Scott D. & Carr M.H. (1978) USGS Map I-1083. 10) Zisk S.H. & Mouginis-Mark P.J. (1981) this volume.